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PATENT & TRADEMARK OFFICE

Patent Application
Atty Docket No. 8146-91484

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	
Andreas V. Tsangaris, et al.	Group Art Unit: 3751
For: Multiple Plasma Generator Hazardous Waste Processing System	Examiner: Steven O. Douglas
	Confirmation No. 3509
Serial No.: 10/776,304	
Filed: February 11, 2004	

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Dear Sir:

Enclosed herewith please find a certified copy of Canadian Priority Patent Application No. 2,418,836 for the above-identified patent application.

Respectfully submitted,

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This is to certify that the documents attached hereto and identified below are true copies of the documents on file in the Patent Office.

Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,418,836**, on February 12, 2003, by **RESORPTION CANADA LTD.**, assignee of Andreas V. Tsangaris, George W. Carter, Michael D. Feasby and Kenneth C. Campbell, for "Multiple Plasma Generator Hazardous Waste Processing System".

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(CIPO 68)
04-09-02

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ABSTRACT

The present invention entails the use of multiple fixed position plasma arc generators dedicated for processing and multiple moveable plasma arc generators for processing assistance and/or final conditioning of the slag prior to exit from the reactor vessel. This processing environment requires very rigid control of reactor vessel geometry to ensure maximum processing efficiency.

MULTIPLE PLASMA GENERATOR HAZARDOUS WASTE PROCESSING SYSTEM

The normal approach for a hazardous waste processing system is to apply a single heat source into a confined space without knowledge of potential cold spots which can develop within the processing environment. Such configurations normally gasify all of the input waste constituents; however, they do not guarantee that all such gaseous elements are subjected to the total temperature environment to ensure total and effective destruction of the more hazardous compounds. A single heat source injected into the centre of the processing environment can create paths close to the refractory wall whereby gaseous elements can traverse without being subjected to the required temperature/residence time combination for complete breakdown. This can result in gaseous hazardous compounds being exhausted from the reactor vessel and/or not fully processed waste constituents being transferred to the slag. Down stream combustion does not achieve the full temperature capability of a plasma processing environment; therefore, hazardous gaseous compounds being exhausted from the reactor vessel results in abnormal complexity through gas handling and potentially excessive pollutants being exhausted to the atmosphere. Not fully processed waste in the slag can result in some or all of this hazardous material remaining in the slag after the slag is extracted from the reactor vessel, which results in the slag exceeding leachate toxicity limits and, thereby, remaining as a hazardous waste requiring continued special disposal or storage requirements.

Other hazardous waste processing approaches attempt to overcome these shortcomings by dramatically increasing the overall reactor vessel temperature, thus ensuring that the minimum temperature encountered throughout the reactor vessel processing chamber is sufficient for adequate thermal decomposition of all waste constituents. This approach solves the problem of insufficient exposure of some waste constituents to the high temperature necessary to achieve good thermal decomposition;

however, in so doing it also creates other problems, including increased plasma arc generator electrode erosion, decreased reactor vessel refractory life, increased heat losses, increased electricity consumption and increased cooling load for the gas handling system. The resultant higher temperature product gas on exit is not only wasteful of plasma arc generator power, but, it is conducive to increased hazardous pollutant compound reformation. Such problems aggregate to dramatically reduced overall system processing efficiency and cost effectiveness.

It is, therefore, the object of the present invention to address these shortcomings and provide a hazardous waste processing environment which ensures total destruction of all hazardous constituents while maintaining a low input power level and a long refractory life. The present invention entails the use of multiple fixed position plasma arc generators dedicated for processing and multiple moveable plasma arc generators for processing assistance and/or final conditioning of the slag prior to exit from the reactor vessel. This processing environment requires very rigid control of reactor vessel geometry to ensure maximum processing efficiency. Positioning and operation of the plasma arc generators provides for a high temperature processing zone where it is optimally required as well as provide adequate heat concentration to melt and force the slag to flow in addition to achieving the lowest possible product gas temperature at the product gas exit port. Two proprietary simulator tools, a plasma gasification process chemical simulator, and a temperature and flow dynamic model simulator, are utilized to assist in final design to ensure optimum reactor vessel geometry taking into consideration the physical characteristics and chemical composition of the input waste, and the required throughput of the system. Processing control is exercised through continuous reactor vessel pressure and temperature monitoring plus continuous product gas flow rate and opacity monitoring.

Most complete breakdown of hazardous compounds is only achieved if a high temperature processing zone is maintained as a solid wall across the entire periphery of

the reactor vessel to ensure that all input waste elements are forced to go through it. In the present invention, the fixed position plasma arc generators dedicated for processing are inserted into the reactor vessel from opposing sides of the reactor vessel with angular displacement relative to each other and aimed to intersect and provide fullest temperature coverage of the hazardous waste feeder opening into the reactor vessel. The focal point of these plasma arc generators is fixed near the centre of the input waste, but they can be discretely adjusted so as to ensure the maintenance of the optimal high temperature processing zone as well as to induce advantageous gas flow patterns around the entire reactor vessel geometry. The moveable plasma arc generators are mounted in the top of the reactor vessel and possesses three degrees of freedom to permit aiming of their plumes at or around the intersection of the plumes from the fixed position plasma arc generators to assist in processing should the need arise, or permit aiming of its plume towards the slag pool at or around the slag exit port for slag conditioning. Processing assistance from the moveable plasma arc generators is advantageous through periods of lowering processing temperature due to unexpected changes in the chemical composition characteristics of the input waste stream. Slag conditioning is essential to ensure that the slag exit port remains open through the complete slag extraction period and to maintain the slag as homogeneous as possible to guard against the possibility that some incompletely processed material may inadvertently make its way out of the reactor vessel during slag extraction . All plasma arc generators are operated on a continuous basis at the discretion of the operator.

The proprietary chemical simulator provides a detailed assessment of the required processing characteristics for most optimum destruction of the waste stream being processed, including:

- Optimal operating characteristics including processing temperature required;
- product gas quantity and quality characteristics including the amount of energy recoverable from it;

- the chemical composition of elements which make up the product gas;
- the quantity of process additives required, i.e. steam for most complete conversion of carbon to a carbon monoxide fuel gas;
- the amount of moisture in the product gas;
- throughput achievable with the particular waste stream under consideration;
- total system design characteristics including optimum design for lowest cost; and
- by-products recoverable.

Input and/or process characteristics can be varied at will within the chemical simulator to visualize processing impacts in order to arrive at the most efficient and effective disposal process for the particular waste stream under consideration. The chemical simulator also serves as a continuous monitoring tool to determine operational characteristics changes which may be required by virtue of changes in the chemical composition of the input waste stream.

The proprietary temperature and flow dynamic model simulator provides isometric printouts of temperature distribution and gas flow characteristics throughout any cross section of the reactor vessel. These features provide an essential tool for optimization of the reactor vessel design to ensure there are no gas paths within the reactor vessel which would permit gaseous elements to exit the vessel without being subjected to the full required processing temperature and residence time. The printout from this simulator dictates the optimum physical positioning of input additive ports and monitors the overall impact of the rate of input additives flow as identified by the chemical simulator. The influence of physical position changes of these ports coupled with the processing additive flow rates can be assessed very readily and the most optimum positions can be determined.

The reactor vessel physical design characteristics are determined by a number of factors:

- the chemical composition of the waste stream to be processed – the reactor vessel internal geometry and size are dictated by the operational characteristics identified by the proprietary chemical simulator through analyses of the input waste stream to be processed;
- the plasma arc generators to be incorporated – the plasma arc generators must be capable of being inserted into the reactor vessel to the desired depth in order to concentrate the high temperature processing zone where it will be most effective while at the same time minimizing plasma arc generator heat losses;
- the position and orientation of the plasma arc generators – the plasma arc generators must be positioned and their plasma heat directed in such a way so as to ensure an adequate travel path for all gaseous molecules produced to maintain a sufficient residence time in the high temperature processing zone to guarantee their full decomposition, including the smallest and most non-polluting molecules; and
- the position of processing additive injection ports – the process additives must be injected where they will ensure most efficient reaction to achieve the desired conversion result. This positioning is primarily identified by the proprietary temperature and flow dynamic model simulator.

The preferred embodiment of the present invention includes a quantity of three plasma arc generators mounted in a circular, refractory lined reactor vessel with a sloping top as depicted in Figures 1A, 1B and 1C. This embodiment includes the following rigidly positioned features:

- two opposing side mounted plasma arc generators with centre line angular displacement and a combined fixed focal point close to the centre of the input

waste stream. The angular displacement provides for turbulence within the input waste and the generated product gas to substantially assist in the efficiency of processing. The fixed focal point generates a total wall of high temperature processing zone through which all elements of the input waste are forced to pass;

- a top mounted plasma arc generator with three degrees of freedom to permit the plasma plume from this generator to be directed to supply plasma heat in support of the side mounted processing plasma arc generators or concentrated on the slag pool at and around the slag exit port. This plasma arc generator is mounted at the rear of the reactor vessel, diametrically opposite the incoming waste front and in close proximity to the by-product exit ports to ensure the maintenance of the full required processing temperature for both of the process by-products;
- a plurality of input waste feed ports to cater to any physical characteristics of the input waste, each of which feeds directly into the processing zone focal area as created by the side mounted plasma arc generators;
- slag and product gas exit ports diametrically opposite to the feed ports to ensure the maximum path possible for both the solid and gaseous process by-products for maximum processing efficiency for hazardous constituent destruction;
- a quantity of up to three process additive input ports for steam injection, strategically located to direct steam into the centre of the processing zone and into the product gas mass just prior to its exit from the reactor vessel;
- a quantity of up to five process additive input ports for air injection strategically located in and around the reactor vessel to ensure full coverage of process additives into the processing zone;
- a quantity of up to four CCTV ports to maintain operator full visibility of all aspects of processing;

- a layer of up to seventeen inches of specially selected refractory lining throughout the entire reactor vessel to ensure maximum retention of processing heat while being impervious to chemical reaction from the input waste stream and processing intermediate chemical constituents;
- a gas exit port positioned vertically and sized specifically to reduce the gas exit velocity so as to minimize the carryover of airborne particles; and
- a flanged lower section to facilitate opening of the reactor vessel for refractory inspection and repair as the need might arise.

The process additives type and quantity are very carefully selected to optimize input waste hazardous constituent destruction while maintaining adherence to regulatory authority emission limits and minimizing operating costs. Steam input ensures sufficient free oxygen and hydrogen to maximize the conversion of the decomposed elements of the input waste into fuel gas and/or non-hazardous compounds. Air input assists in processing chemistry balancing to maximize carbon conversion to a fuel gas (minimize free carbon) and to maintain the optimum processing temperatures while minimizing the relatively high cost plasma arc input heat. The quantity of both additives is established and very rigidly controlled as identified by the proprietary simulator outputs for the waste stream being processed. The amount of air injection into the process is very carefully established to ensure a maximum trade off for relatively high cost plasma arc input heat while ensuring the overall process does not approach any of the undesirable process characteristics associated with incineration, and while meeting and bettering the emission standards of the local area.

The flanged lower section provides for the ease of inspection and repair of the refractory lining as the need might arise. The refractory lining in the bottom section of the reactor vessel is much more prone to wear and deterioration since it must withstand higher temperatures from the operating plasma arc generators and it is continuously in

contact with the hot molten slag. The refractory in the lower section is, therefore, designed to consist of a more durable "hot face" than the refractory on the reactor vessel walls and top. In other embodiments the lower section may also be water cooled through the outer shell to prevent abnormal deterioration of the refractory lining. A duplicate lower section may also be constructed to facilitate faster return of the processing facility to operational status through periods of refractory repair or to provide for alternate construction to accommodate processing of more demanding and/or corrosive input waste streams.

Process control is automated through up to three operational characteristics:

- reactor vessel pressure changes attributable to a non-optimal feed rate, input waste stream chemical characteristic changes or potential blockages in the product gas handling system;
- reactor vessel and product gas temperature changes attributable to a non-optimal feed rate or input waste stream chemical characteristic changes; and
- product gas opacity reading increases attributable to non-optimal processing.

It has been found through many years of plasma gasification processing that the amount of particulate matter in the product gas stream has a direct relationship to the emission rate of polluting elements. Pollutants tend to adhere to particulate matter which assists their exit from the reactor vessel and through the exhaust piping. It has been found that minimizing the amount of particulate matter in the gas stream also minimizes the emission rate for most pollutants. An acceptable manner of determining changes in the amount of particulate matter in the gas stream is to monitor the gas stream opacity and establish a baseline for an acceptable concentration in accordance with regulatory authority restrictions within the location of processing. The proprietary chemical simulator identifies the amount of process additives required to obtain this low level of particulate matter emissions which serves as the baseline for start-up processing

operations. Thereafter, real-time feedback of opacity within the product gas piping provides a mechanism for automation of process additive input rates, primarily steam, to maintain the level of particulate matter below the maximum allowable concentration.

A typical embodiment of the opacity monitor is shown in Figure 2. A primary feature of this embodiment is the maintenance of deposition free sensor elements to ensure accuracy of readings. The prevention of deposition on the sensor elements is achieved by either of two methods; the provision of a small amount of nitrogen across the face of each element to prevent airborne particles from settling, or the maintenance of a slightly negative pressure in this portion of the gas handling system to ensure airborne particles are drawn past the sensor elements. Typically, nitrogen is used unless it will be detrimental to the chemical composition of the gas stream depending on the waste stream being processed and the potential use to be made of the gas on exit.

Other embodiments of the present invention may include varying numbers of plasma arc generators, steam injection ports, air injection ports and CCTV ports depending on the waste stream under consideration and the desired operational characteristics as determined by the proprietary chemical simulator and the proprietary temperature and flow dynamic model simulator.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate the complete preferred embodiment of the present invention according to the best modes presently devised for the practical application of the principles thereof and in which:

FIG 1A is a side elevation of the reactor vessel cut away to show the refractory lined reactor vessel interior along a line through the centre of the solid waste feeder and the product gas exit ports.

FIG 1B is a side and back pictorial of the reactor vessel showing the positioning of the input and output ports which can be viewed from this perspective.

FIG 1C is a top pictorial of the reactor vessel showing the input and output ports as viewed from this perspective.

FIG 2 is a side section schematic view of the opacity monitor useful in the invention.

Referring now to FIGS 1A, 1B and 1C of the drawings, a side elevation cut away view of the refractory lined plasma gasification reactor vessel 10 according to the present invention is shown together with top and side outside viewpictorials.

10a – refractory lining

10b – refractory lined reactor vessel lower section

10c – reactor vessel lower section attachment flange

11 – profile of extremely high temperature processing zone

12 – sloping top of reactor vessel to ensure top mounted plasma arc generator 14 can deliver its heat fully to the required areas with minimum insertion of the plasma arc generator into the reactor vessel

13a & 13b – opposing side mounted plasma arc generators with centre line angular displacement

14 – top mounted plasma arc generator with three degrees of freedom

15 – slag pool collection area

16 – gas exit port

17 – slag extraction port

18 – solid waste feed input port

19a & 19b – liquid waste input ports

20 – reactor vessel preheat burner port

21a, 21b &21c – steam injection ports strategically located to ensure the steam additive input blankets the entire processing zone for maximum efficiency

22a, 22b, 22c, 22d & 22e – air injection ports strategically located to ensure the air additive input blankets the entire processing zone for maximum efficiency

23a, 23b, 23c & 23d – CCTV inspection ports strategically located to ensure the operator has complete and continuous visibility of all aspects of processing

Referring now to FIG 2 of the drawings

24 – product gas piping showing mounting of opacity monitor

25 – opacity monitor

25a – opacity monitor transmitter

25b – opacity monitor receiver

25c &25d – water cooled sections of opacity monitor

26a & 26b – nitrogen purge elements to direct flow of nitrogen to keep airborne particulates from depositing on the opacity monitor sensor elements

27 - slightly negative pressure zone in product gas piping

Operations within the processing plant commence with a fossil fuel burner being inserted into the preheat burner 20 in reactor vessel 10. After the maximum temperature has been achieved in vessel 10 with this burner, the burner is removed, preheat port 20 is sealed and plasma arc generators 13a, 13b and 14 are inserted and turned on to bring the total reactor vessel temperature to the desired operating temperature. At this time, a prescribed flow of steam is established through steam ports 21a, 21b and 21c and a prescribed flow of air is established through air ports 22a, 22b, 22c, 22d and 22e. The prescribed flow of both steam and air is as determined by the chemical simulator for the type of waste to be processed. Feeding of waste into vessel 10 is then commenced through solid waste port 18 and/or liquid waste ports 19a and 19b depending on the type of waste being processed. Input waste is decomposed within the extremely high temperature processing zone 11 to form a molten solid and a product gas. The molten solid, referred to as slag, flows to the slag pool collection area 15 where it resides until in is extracted from vessel 10 through slag extraction port 17. Slag extraction through slag

extraction port 17 can be continuous when the input waste material contains adequate amounts of slag producing constituents. The product gas exits vessel 10 through gas exit port 16.

The preferred embodiment of the refractory lined plasma gasification reactor vessel 10 contains up to three steam injection ports 21a, 21b and 21c, up to five air injection ports 22a, 22b, 22c, 22d and 22e, and up to four CCTV inspection ports 23a, 23b, 23c and 23d. The specific quantity of the steam and air injection ports for any particular embodiment of the invention is dictated by the proprietary chemical simulator in its assessment of the chemical composition of the waste stream to be processed. In any embodiments where lesser quantities of any of thesc ports are used, the physical positioning of the lesser quantity is dictated by the proprietary heat and flow dynamic model simulator in order to maintain the optimal operational characteristics as detailed by the proprietary chemical simulator.

Plasma arc generators 13a and 13b provide a consolidated front of an extremely high temperature processing zone 11 throughout the complete inside of reactor vessel 10 between the input waste ports 18, 19a and 19b, and the processing by-product exit ports 16 for the product gas and 17 for the molten slag. Plasma arc generators 13a and 13b have fixed focal points to ensure that the profile of the high temperature processing zone remains complete and optimal. Plasma arc generator 14 has three degrees of freedom to permit it to add high temperature assistance anywhere it is required within vessel 10, ranging from heat assistance to the processing zone profile 11 created by plasma arc generators 13a and 13b to ensuring that the slag in the slag pool collection area 15 is fully processed and slag exit port 20 is kept open during all slag extraction periods.

The product gas on exit from reactor vessel 10 through gas exit port 16 proceeds through product gas piping 24 and passes through opacity monitor 25. The opacity monitor provides a measure of the amount of airborne particulates in the product gas by

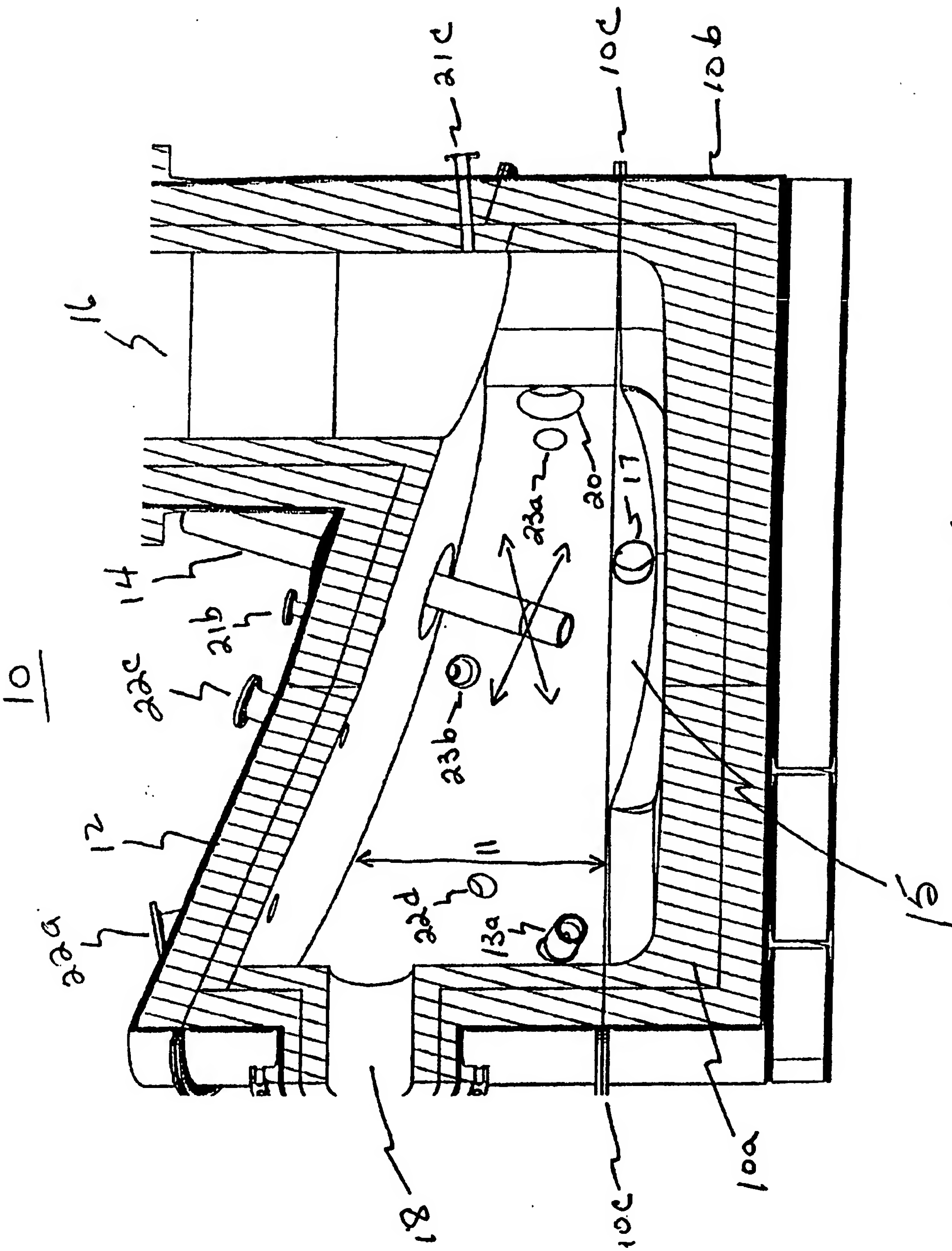
communication between opacity monitor transmitter 25a and opacity monitor receiver 25b. Opacity monitor 25 sections 25c and 25d which contact the hot product gas piping 24 are water cooled to ensure opacity monitor transmitter 25a and opacity monitor receiver 25b are not overheated. Nitrogen purges 26a and 26b prevent deposition of any airborne particles from settling on the opacity monitor transmitter sensor 25a or the opacity monitor receiver sensor 25b which would impede opacity monitor sensitivity and, hence, accuracy. Alternatively, instead of the nitrogen purges 26a and 26b, a slightly negative pressure area 27 can be maintained to prevent airborne particles from depositing on either the opacity monitor transmitter sensor 25a or the opacity monitor receiver sensor 25b. Opacity monitor 25 reading is passed to the control console for process control purposes. Process control is effected through adjustment of steam flow rate through steam injection ports 21a to 21c, which, in turn, simultaneously affects the air input through air injection ports 22a to 22e. Any changes in steam or air injection into the process also affects the generated product gas flow rate.

The process operator maintains full and continuous visibility of all aspects of processing within vessel 10 through CCTV inspection ports 23a, 23b, 23c and 23d.

Inspection and repair of the reactor vessel refractory lining 10a as required is facilitated by removing refractory lined reactor vessel 10 lower section 10b by means of disconnection of flange 10c.

WHAT IS CLAIMED IS:

1. A waste and/or hazardous waste disposal apparatus and process with improved waste constituents destruction and lower input power levels, comprising: a first plurality of fixed-position plasma arc generators; a second plurality of moveable plasma arc generators for enhanced processing of waste and/or for conditioning of slug prior to expulsion; and predetermined reactor vessel geometry within which said first and second pluralities of generators are disposed.


10
10a
10b
10c
10c
11
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13a
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22c
22d
23a
23b

FIG 1A

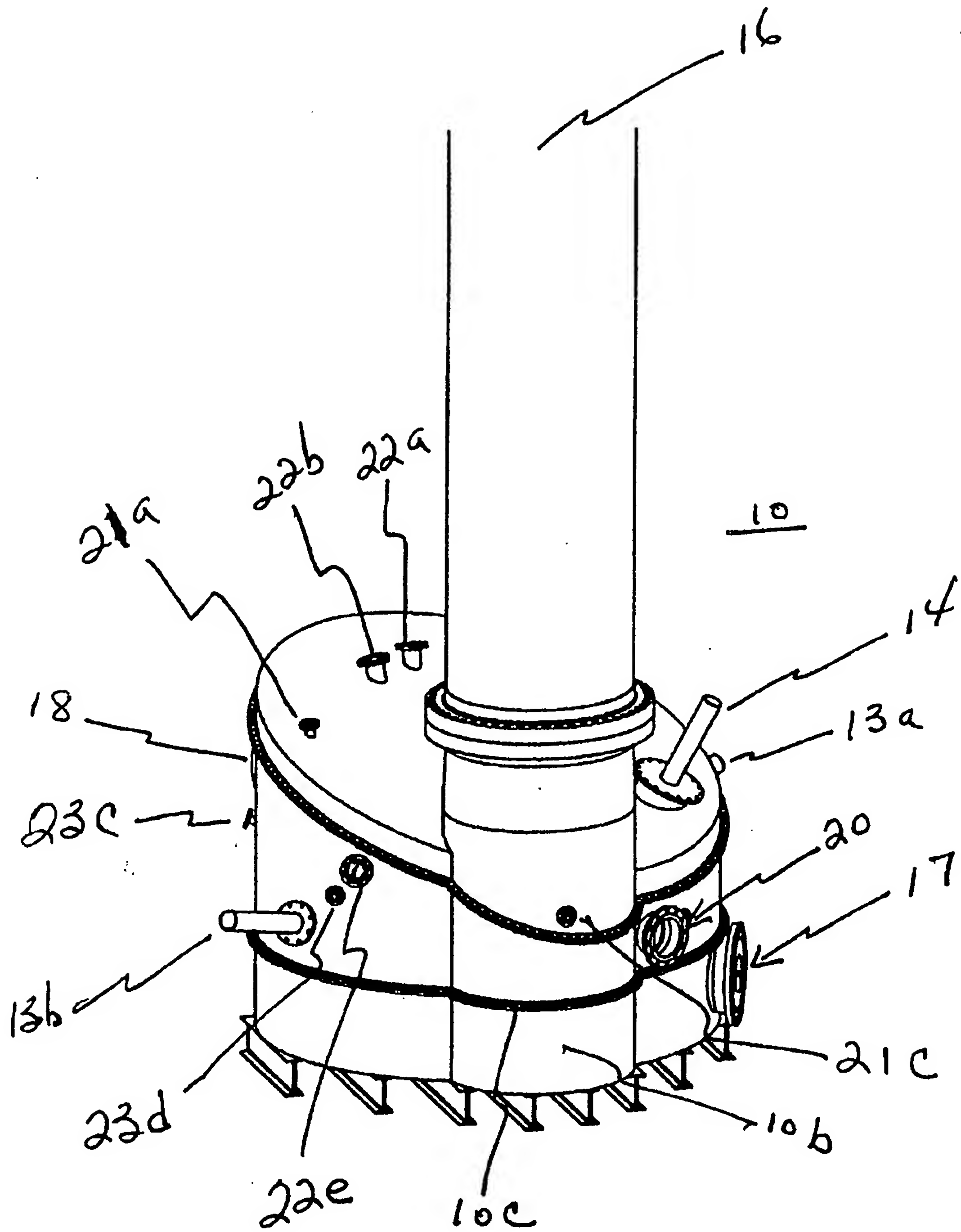
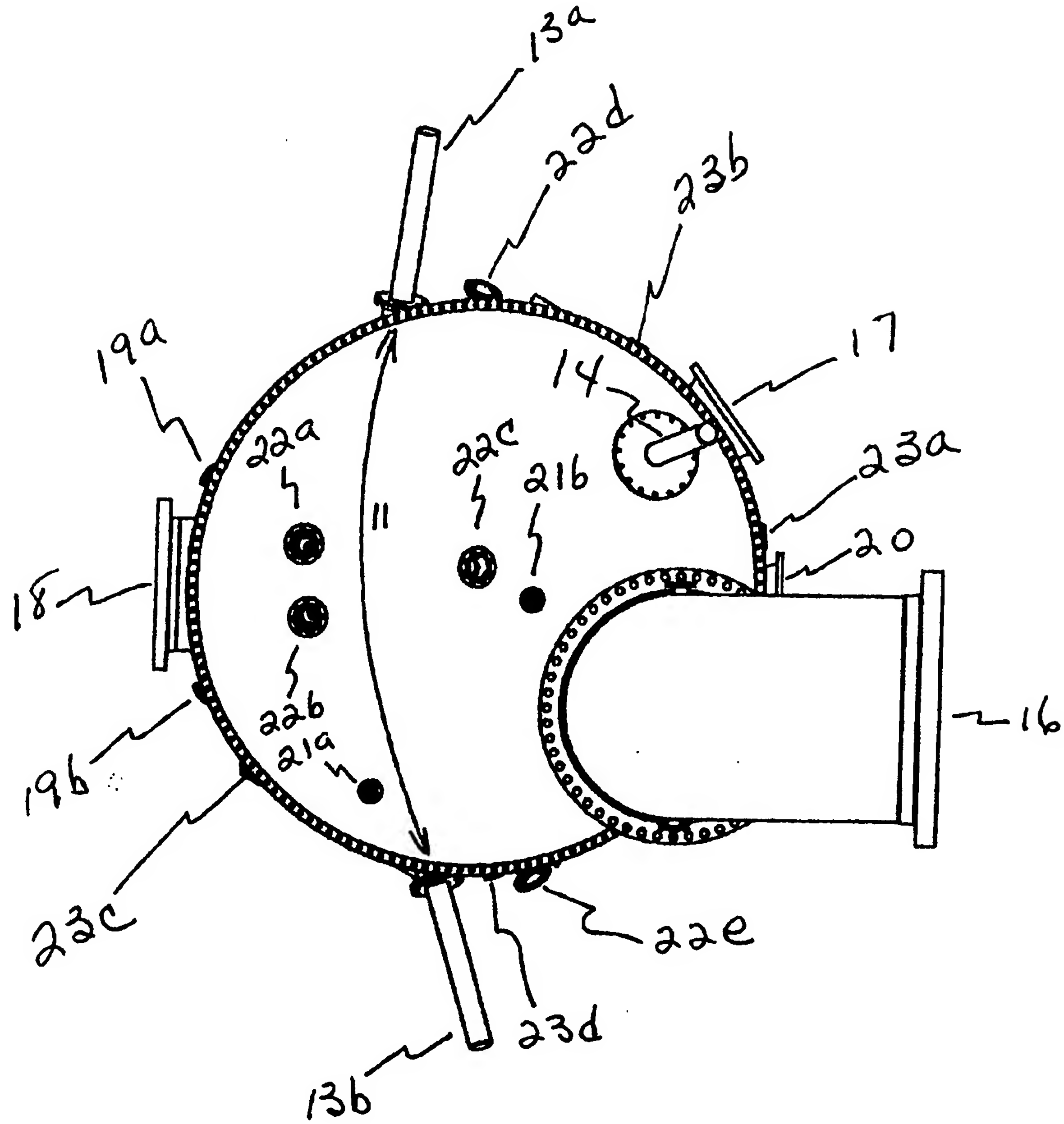


FIG 1B


13a
22d
23b
17
14
19a
22a
22c
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23a
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11
18
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19b
21a
23c
22e
23d
13b

FIG 1C

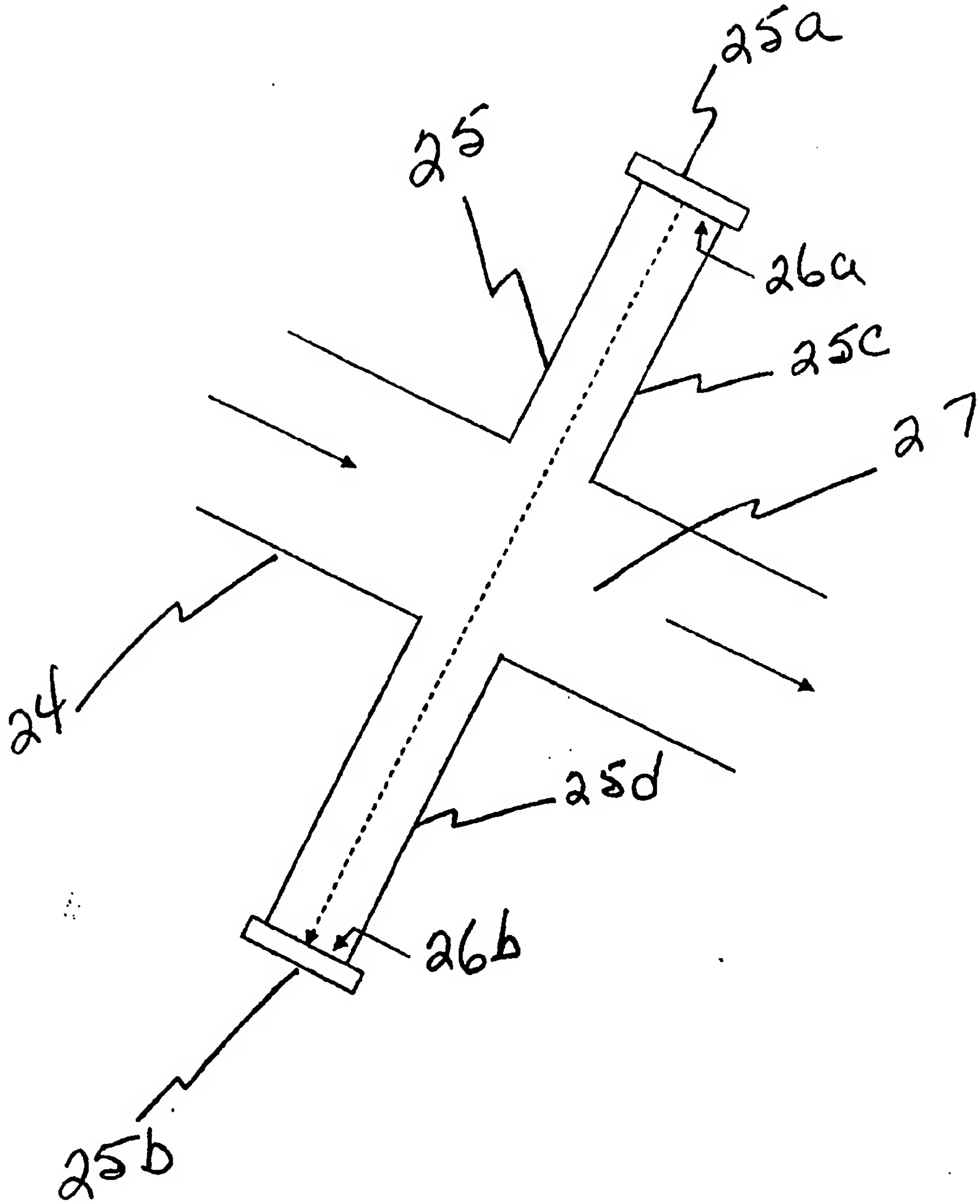

FIG 2